15

Electric Railway Traction

British Electrification Schemes

ALTHOUGH conversion work in this country is making haste slowly so far as mileage is concerned, there is little hesitancy in extending electrification from existing systems, not only in branching out further from the centre, but also in providing increased facilities to meet the greatly increased passenger traffic which the first conversions have brought in their wake. Into such categories fall the schemes now being promoted or pushed forward by the London Passenger Transport Board and the Southern Railway. In the former case the construction of a new tube section of only two miles in length will bring to millions of passengers benefits far in excess of its mileage value, and the possibilities which will follow the electrification of the Nunhead-Lewisham line of the Southern Railway are just as great, for in addition to allowing the diversion of certain trains from London Bridge to Holborn, this conversion will permit of the much-needed service to Victoria from the Eastern Section suburban lines. Despite the conversion of the Sevenoaks, Sanderstead, and Lewisham lines, still further improvements could be made in the Southern suburban area, principally by the provision of two more tracks between Borough Market junction and Metropolitan junction, where the one up and one down lines severely limit the number of suburban trains which can be worked in and out of Charing Cross as compared with Cannon Street. The activities of the L.N.E.R. in thoroughly modernising the Tyneside electrified lines, and the Minister of Transport's recent reply in Parliament regarding the London lines, fathers the hope that certain other suburban sections of that company's system will be taken in hand, and if the lead given by the Hastings extension at one end of the country and the Glasgow subway at the other bears any fruit, it may be that 1935 will be a year of perspiration rather than hesitation in the electrification of British railways.

Electrification as an Economic Force

THERE are throughout the world various electrified railway systems which are not so well-known as they should be, simply because they are not situated in highly-developed countries. Nevertheless, they have proved successful almost without exception, and in some instances have solved economically problems which previously were thought to be incapable of solution except by the construction of entirely new railway lines. Further, in certain examples these electrified lines have contributed in no small measure to the economic welfare of the country by providing cheap, fast, frequent, and clean transport while at the same time forming a basic load for the development of a general electric system, for which there would otherwise be but little hope of profitable operation. A case in point is to be found in Morocco, where the electric railways consume something like 18,000,000 kWh. of energy a year, largely generated by the natural water power from the Atlas Mountains. This load is being used as the economical base by means of which a number of small consumers can be supplied with cheap light or power. Moreover, the steeply-graded lines from the Atlantic seaboard to Marrakech and the towns in the phosphate districts can be most efficiently operated by electric traction, and this advantage also applies to the important Bône-Oued Keberit line in the neighbouring state of Algeria, which, incidentally, consumes almost as much current as the Moroccan lines, although much shorter in length. Both of these railway systems are described in detail elsewhere in the present issue. The success of the Algerian line, coupled with a desire for more efficient working over a wider area, has led to authority being given for the conversion of two divisions of the Moroccan-Tunisian trunk line situated in the eastern part of Algeria. It is not beyond the bounds of possibility that eventually the whole 1,505 miles of this international line will be operated by electric traction, and there is little doubt that, should this come to pass, the smoothness and cheapness of working which electrification permits will greatly increase the traffic and the prosperity of the three countries concerned.

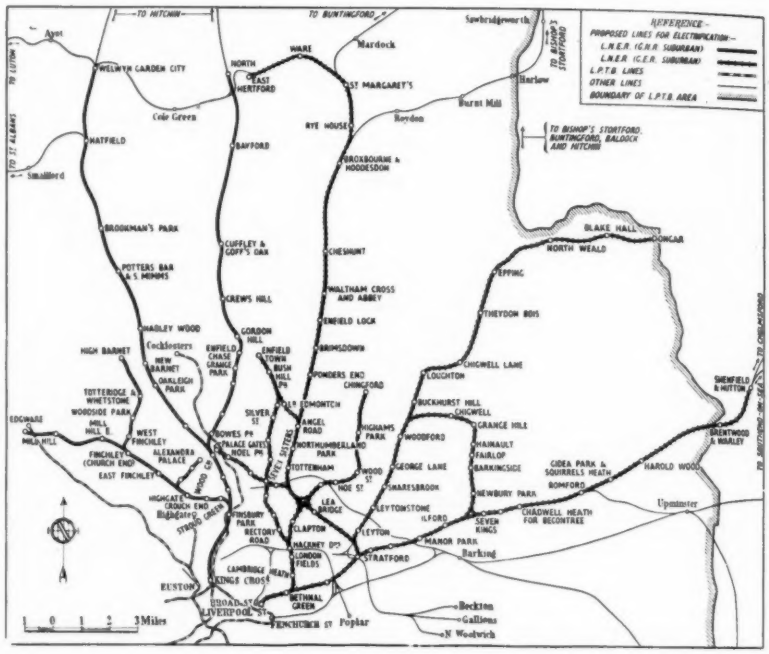
Regeneration on D.C. Lines

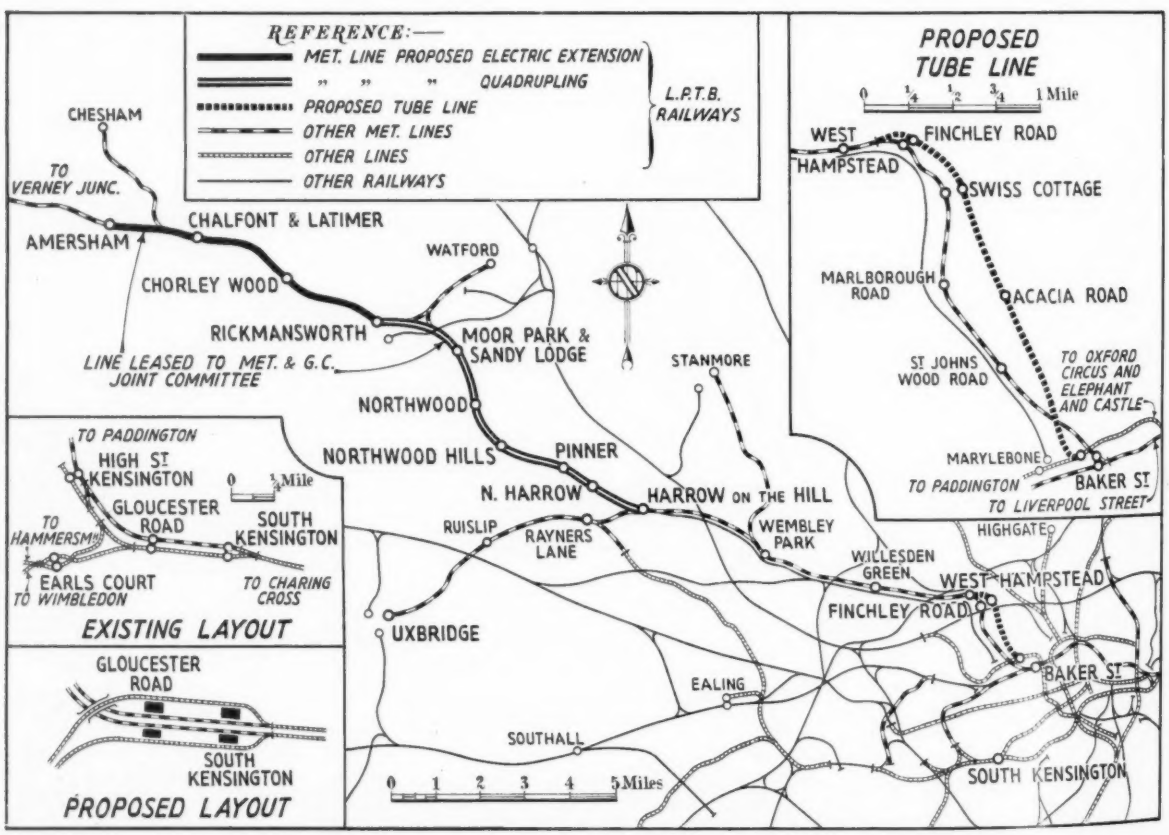
THE merits of regenerated energy on direct current railways are not always appreciated in their true proportions. There is a tendency to overrate the ninepence for fourpence idea of having current sent back into the system simply by putting a motor-generator set on the locomotive. Even on the steepest lines, the amount of power which gets back to the supply side of the substations is not large, for most of the energy is transferred directly back to the overhead line and fed to trains going uphill. This is certainly getting useful power for nothing, but it is doubtful whether the saving of current is in itself of sufficient magnitude to warrant the extra expense, although a certain 70-mile heavily-graded line is known to regenerate about 15 per cent. of the consumption, of which about 12 per cent. is used directly by trains going up the grade, and only 1½ per cent. actually returned to the supply system. Moreover, the use of regenerative features has precluded the installation of mercury rectifiers in the substations, and although by means of grid control it is now possible to construct a rectifier capable of dealing with regeneration, no such application is yet operating in traction service so far as we are aware. The greatest advantage of regeneration is probably the remarkable possibilities which it offers for the control of heavy trains on down grades. It is not suitable for making stops, and for this purpose the air brake is in general use, but regeneration is invaluable in holding the train to a steady speed from which a stop can be made easily and quickly. The elimination of run-aways and the knowledge that the train will descend a long grade at a definite speed is a great asset to the operating and timetables officers, as well as to the civil engineer, and if the line is at all a busy one, the benefit is passed on to the public in the form of more regular schedules and greater punctuality.

NEW BRITISH ELECTRIFICATION SCHEMES

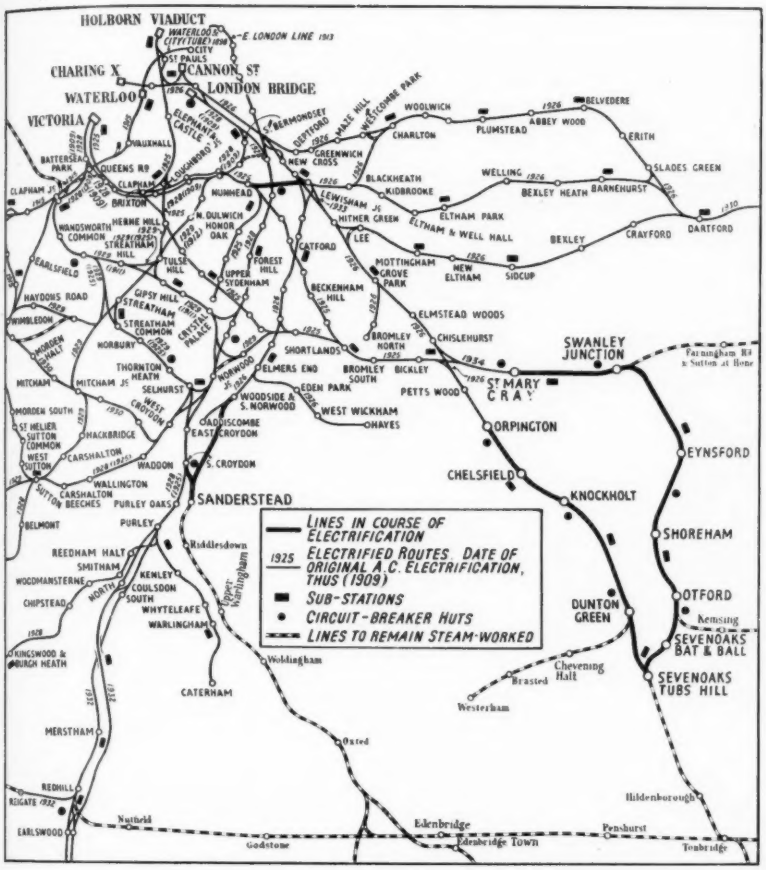
Several projects now under way or being considered will have far-reaching effects on passenger transport in London and the Home Counties

THERE is a good deal of activity on British railways at the present moment in the way of electrifying lines, which, if of no great length, are of great importance in the matter of traffic density and in the easy travel facilities which they offer to the public. Hard upon the heels of the modernisation of the Tyneside electric lines of the L.N.E.R., comes the announcement that the Southern Railway is once again to extend its electrified mileage by the conversion of the Lewisham-Nunhead and Woodside-Sanderstead lines. The work on the Sanderstead line has been considered judicious in view of the





Top: Map showing L.N.E.R. London suburban lines for which electrification proposals have been made
Bottom: Map showing new tube, electrification, and widening works proposed by the L.P.T.B.



Map of Southern Railway suburban area, showing new lines being electrified

rapidly-extending residential district, and the train service will be made up of a portion of the service now running from Charing Cross and Cannon Street to Addiscombe, although it is possible that services may be run from Victoria or from London Bridge via Norwood Junction. The conversion of the Lewisham-Nunhead line will allow of the diversion of certain trains from London Bridge to Holborn, but its greatest possibility would seem to be in the running of services from the Eastern Section suburban lines to Victoria. Those sections of the Southern suburban lines which are already under conversion, viz., the routes from St. Mary Cray and Orpington to Sevenoaks, are scheduled to be opened to regular electric operation on January 1, 1935. Work is about to begin on the new Western Section line from Motspur Park to Leatherhead, which will be worked by electric traction, and good progress has been made on the Eastbourne and Hastings extension; it is anticipated that trial runs on certain sections of this line will commence shortly after the turn of the year.

On the other side of the Thames, the London Passenger Transport Board is seeking powers to make extensive improvements in the operation of traffic on the Metropolitan line from Baker Street. In the first place, it is desired to electrify the double-track line from Rickmansworth, the present electric terminus, to Amersham, a distance of $6\frac{1}{4}$ miles, and to quadruple the existing double-track electrified line from Harrow to Rickmansworth. The second part of the programme is to build a new tube from Baker Street station to a point on the Metropolitan line between Finchley Road and West Hampstead, where some rearrangement of the lines, apparently, will have to be made; new tube stations will be built at Finchley Road, Swiss Cottage, and Acacia Road. This tube, 2.4 miles long, will have a great operating advantage, in that it will be possible for passengers from the Metropolitan line to be taken directly into the centre of London on the Bakerloo line, and so lessen the pressure of the interchange traffic at Baker Street. It will also solve the acute problem of the Baker Street-Finchley Road bottleneck by providing an extra pair of tracks between these points. As the tube will not be large enough to accommodate Metro stock, such a service would necessitate the running of the Bakerloo trains out to Harrow, and possibly beyond.

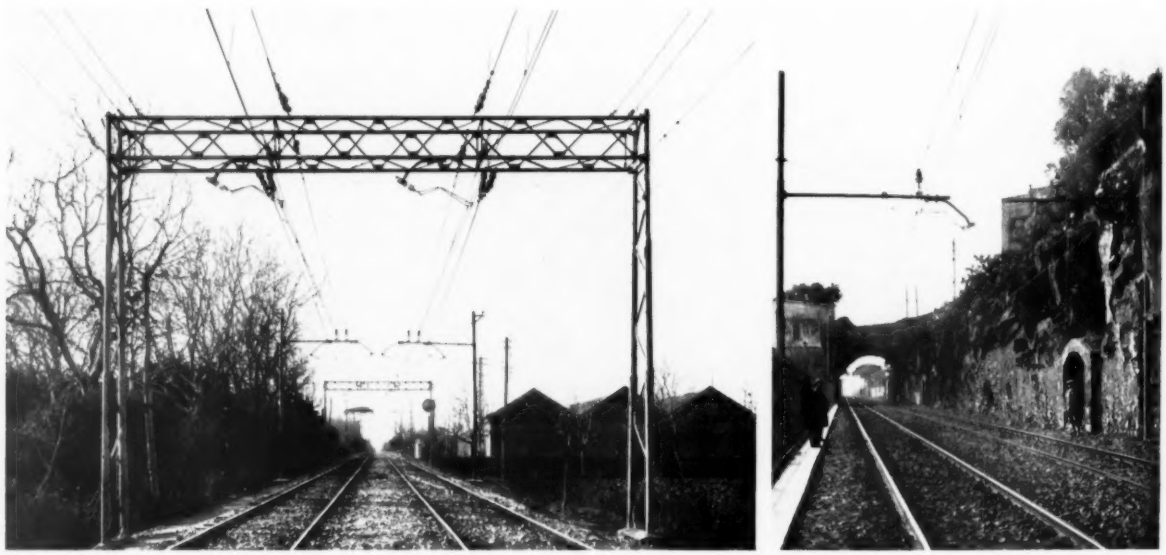
Other railway improvements included in the Bill to be presented before the next Session of Parliament include the extension of the Uxbridge branch for a short distance to Uxbridge High Street, and the construction of a burrowing junction near Gloucester Road, Kensington, so that Inner Circle trains will no longer foul the track of east-bound District trains. At the same time the tracks will be rearranged so that Inner Circle trains will be able to utilise the centre platforms at South Kensington station. Aldgate East station, at the other end of the District line section of the Inner Circle, is to be re-sited, and moved about 550 ft. to the east of its present situation. To facilitate exchange traffic the new station will have an island platform 425 ft. long. The work here will also include rearrangement of the tracks to give easier curves, and will cost approximately £330,000. The cost of the complete works included in the Bill will be well over £2,500,000. The extensive re-modelling of Leicester Square tube station, which has been under way for some 18 months, will be finished in the early part of next year.

According to a recent statement of the Minister of Transport, the electrification of the L.N.E.R. lines out of Liverpool Street will take precedence over those out of King's Cross. The line most urgently requiring conversion is that through Stratford to Ilford, or even beyond, where the suburban lines parallel the main line tracks of the Great Eastern section. As Sir Ralph Wedgwood, Chief General Manager of the L.N.E.R., has already stated that "any scheme having for its object merely electrification of the existing line to Ilford would not give an increased capacity sufficient to provide any real relief for carrying rush-hour passengers, nor enable an adequate return to be earned on the capital expenditure," it is probable that any new works will include widened lines from Stratford into Liverpool Street. Traffic over the Chingford, Enfield, and Palace Gates lines is also far more than sufficient to warrant electrification, but owing to the special methods of working the position is not so serious as on the route to Stratford where similar principles could not be applied. What will be done withthe Great Northern section suburban lines centring on King's Cross is not known, but it is not likely that any conversion work will be undertaken for some time. Estimates have shown that about £3,700,000 would be required for the electrification of the Edgware, Barnet, Hertford and Welwyn lines.

ELECTRIFICATION OF THE NAPLES - SALERNO LINE

Latest Italian extension of the high-tension direct current system

THE electric service on this main line was inaugurated on October 28, and forms the first d.c. extension completed under the 4,200,000,000 lire programme of electrification promoted by the Italian Minister of Communications in 1933. This double-track line has a route length of 53·1 km. (33 miles) and a track mileage of 150 km. (93¼ miles). The maximum gradient on the line is 1 in 40, and the minimum radius of curves 15 chains. The electrification has been extended to the branch line from Torre Annunziata to Gragnano, which is single track and has a route length of 10·4 km. (6½ miles), and a track mileage of 25 km. (15½ miles). These lines are electrified on the d.c. 3,000-volt system. The section of the contact lines is 317 sq. mm. (0·491 sq. in.) along the line, and 158 sq. mm. (0·245 sq. in.) in the stations. The line is fed by the existing substation at Naples-Poggioreale and by a new substation at Cava dei Tirreni. This latter is of the open type and contains two 60-3 kV. transformers with corresponding main and section switches. Two mercury arc rectifiers, each of 2,000 kW. capacity, have been installed, and a third unit is to be added in the near future. The rectifiers are provided with polarizable grids to allow recuperation of energy and for facilitating protection against return arches. Suspension is of the catenary type with counterweight tension arrangements. The contact wires over the line are mechanically independent from those in the stations, electric continuity being ensured by remote-controlled section switches.



Two types of overhead construction as used on the new 3,000-volt d.c. electrified extension of the Italian State Railways from Naples to Salerno

Another Link in Central German Electrified Network

On October 6 steam traction came to an end on the Halle-Köthen-Magdeburg section of the Reichsbahn with the change over from summer to winter timetables. This section forms the last part of the circular route Leipzig-Bitterfeld - Dessau - Magdeburg - Köthen - Halle - Leipzig, so that the principal railway route of central Germany is now entirely electric. This fact is of importance, because the route via Köthen carries considerably more traffic than that via Dessau-Bitterfeld, which has been electrically worked for many years. Although that line was the first section of the former Prussian State Railways to be converted to electric operation, from a traffic point of view the Halle-Köthen line is vastly more important.

This work has cost upwards of RM. 8,000,000 and has taken about 12 months to complete. It has had the effect of increasing the power demand on the Reichsbahn power station at Muldenstein by 35,000,000 kWh. annually, thus raising the coal consumption there by 140,000 tons. On the 87 km. (54 miles) of double-track route, about 400 km. (250 miles) of wire have been used. A substation, placed partly in the open and partly covered, has been erected at Köthen, and here the power received from Muldenstein station is transformed to feed the contact wires at the correct voltage, viz. 15 kV. 16⅔ cycles single-phase. The new installations were inspected by the Presidents of the Halle and Hanover divisions on the day before the electric service was introduced, and a decorated train was used for the tour of inspection.

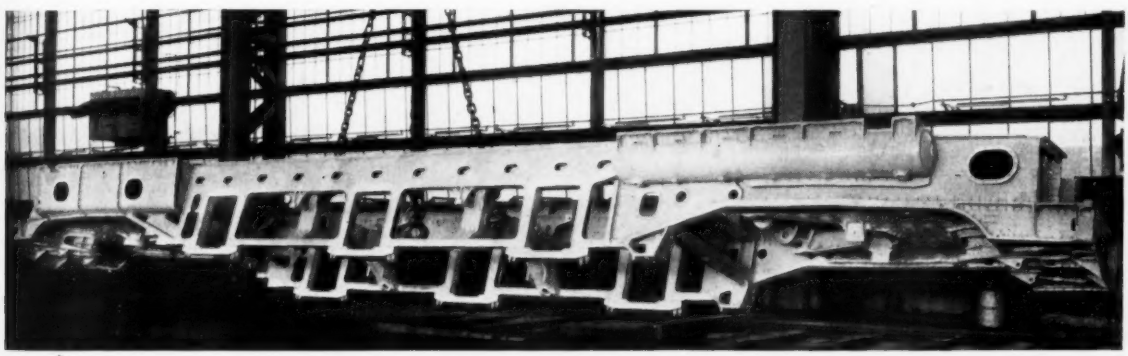
NOTES AND NEWS

South African Electrification.—Work on the extension of the electrification of the Cato Ridge-Durban section, as recommended by the Granet Commission, was commenced in July, and over 200 towers for the transmission line have now been erected. On the Daimana-Harrismith line, on which conversion work has been proceeding for 12 months, the masts are erected for 56 miles and the catenary wire for 45 miles. It is expected that electric operation over this division will effect a yearly saving of £26,500 in operating costs.

Spanish Rolling Stock Orders.—Orders have been placed on behalf of the Norte for 12 express and 24 ordinary passenger electric locomotives, and 30 motor coaches with trailers, for service on the Madrid-Avila-Segovia lines, conversion work on which has now begun. All the above orders, and also that for the overhead line equipment, have been placed with Spanish companies.

Indian Electrification Results.—It is estimated that during the slump years 1930-31 and 1931-32 the electrification of the G.I.P. Railway from Bombay to Igatpuri and Kalyan showed respective returns of 3·12 and 3·58 per cent. on the gross capital outlay. The savings in operating expenditure due to electrification were 28·5 lakhs of rupees in 1930-31 and 32·5 lakhs in 1931-32. On the B.B. & C.I. Railway the electrified suburban system showed a return of 1·29 per cent. in 1930-31 and 2·22 per cent. in 1931-32. The approximate yearly saving in working expenses over the 23 route miles of track electrified is 4 lakhs of rupees, but normally the savings and returns would be higher.

Extension of Copenhagen Suburban Electrification.—On November 1 a further stage of the electrification of the Copenhagen suburban lines was opened, from Copenhagen to Valby, a distance of 3·9 km. (2·4 miles), as shown on the map in the *Electric Railway Traction Supplement* for May 4. The line has four tracks until Enghave station, of which two are electrified, and three tracks to Valby, of which one is electrified. A new station named Dybbolsbro has been opened between Copenhagen and Enghave. A 20-min. service is being given, the trains from Klampenborg running through Copenhagen to Valby. The electrified lines now total 27·6 km. (17·2 miles). As the increase in traffic on these lines has been greater than expected, six additional three-car trains have been ordered, and in addition a new station, named Borups Alle, will be opened shortly on the line from Frederiksberg to Vanlose. The time allowed to cover the 17·2 km. (10·7 miles) from Valby to Klampenborg is 29 min., including all intermediate stops.



Cast-steel bedplate of express electric locomotive, Pennsylvania Railroad

Russian Electric Locomotive Factory.—The electric locomotive works which is now being laid down at Kashira, near Moscow, is to commence production in 1936, but the full capacity will not be attained until 1939-40. A new city for 40,000 inhabitants is being planned round the works, the nucleus of which is the colony of the 4,000 workers now employed.

Moscow Suburban Lines.—The electrification of the suburban lines running north-east from the Northern station in Moscow to Mitischi, Sofrino, Bolshevo, and Sagorsk now extends to a mileage of about 110. The electrification has cost 31,600,000 roubles, and saves approximately 70,000 tons of coal a year. Direct current at 1,500 volts is used in the contact wire, and there are six substations with an aggregate capacity of 16,000 kW.; the yearly consumption of energy averages 23,000,000 kWh. The service is maintained by 32 trains of three or four cars which make an average daily run of 280 miles, and a maximum of 370 miles. The schedule speed of the stopping trains is 24-26 m.p.h., and of the fast trains 32-37 m.p.h. Over 70,000,000 passengers were carried in 1933, as many as 300,000 being transported in one day.

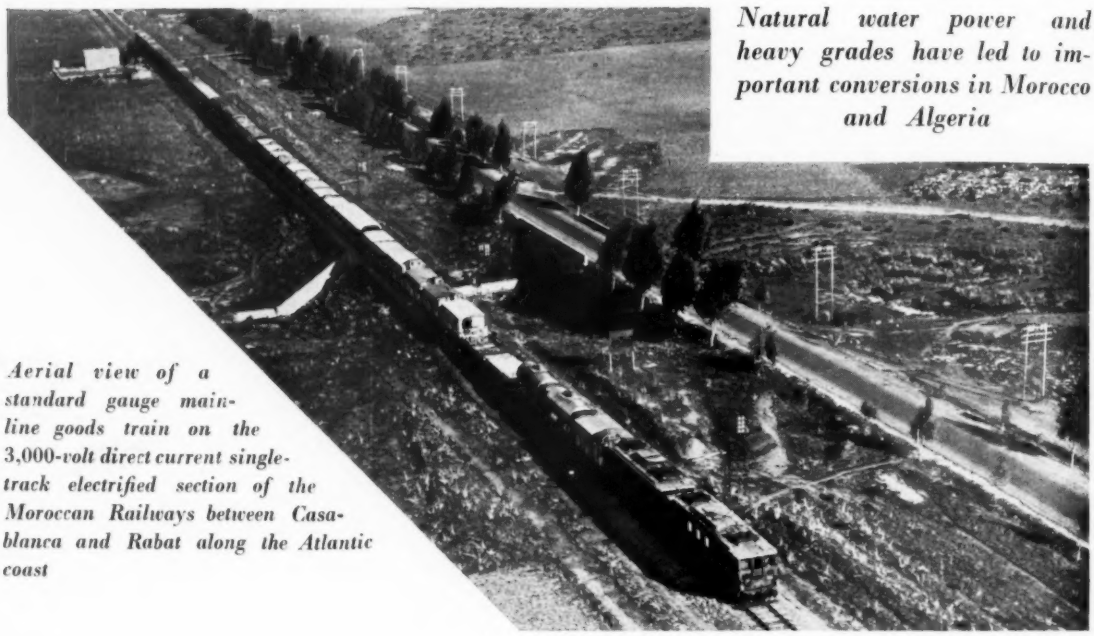
Pennsylvania Locomotives.—The 28 2-Co-2 electric locomotives of 3,750 h.p. ordered by the Pennsylvania Railroad (as announced in the September 21 issue of this Supplement) are being built up on single-piece cast-steel bedplates as shown in the accompanying illustration. Cast at the Eddystone plant of General Steel Castings Corporation, the bedplate includes air, water, and oil reservoirs, and extends over a length of 60 ft., a width of 10 ft. 4½ in., and a height of 4 ft. 9½ in. The finished weight is 26 tons. Another 57 streamlined locomotives have just been ordered.

Hungarian Electric Material.—Metropolitan-Vickers Electrical Co. Ltd. have just shipped the last consignment of electrical machinery for the substations and locomotives of the Hungarian State Railways extension of electric traction from Komarom to Hegyeshalom, on the Budapest-Vienna main line. The journey was made via the Harwich-Zeebrugge train ferry, and the same trucks were used for the whole distance from Trafford Park to Budapest.

Another Swiss Electric Line.—Electric traction has just been extended to the St. Margrethen-Buchs section of the Rorschach-Sargans line on the eastern frontier of Switzerland. This division is 24 miles long and a yearly saving of 267,000 Sw. fr. in the operating cost is expected.

RAILWAY ELECTRIFICATION IN NORTH AFRICA

Natural water power and heavy grades have led to important conversions in Morocco and Algeria



Aerial view of a standard gauge main-line goods train on the 3,000-volt direct current single-track electrified section of the Moroccan Railways between Casablanca and Rabat along the Atlantic coast

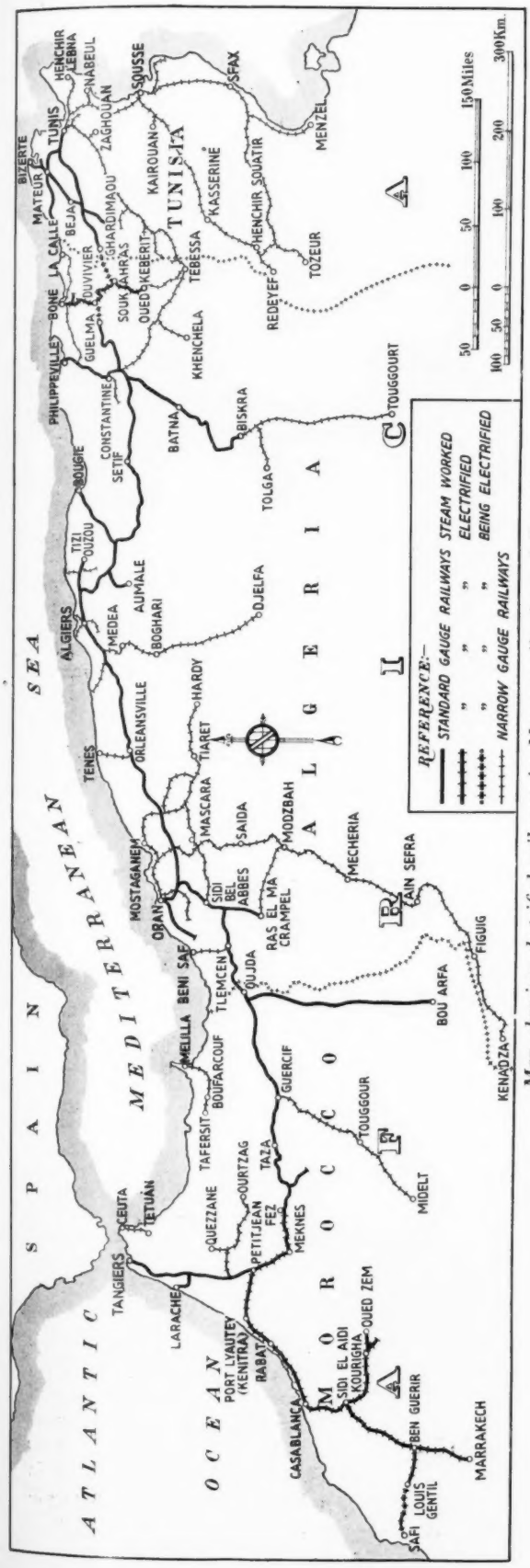
IN a land which so short a time ago was little more than desert, it may seem surprising to find over 400 miles of trunk railways worked with up-to-date equipment by electric traction. But the French authorities in Morocco have not been slow in realising the possibilities of this medium of operation for both new and existing lines, and it appears that a scheme of general electrification is being pursued methodically. Although such a comprehensive programme of conversion is not likely to mature in Algeria, the merits of electric working on difficult sections have proved to be of great value, and an important mineral line has been converted at a lesser cost than would have been entailed by doubling the track, and yet has been given a greater traffic capacity. The first section of main line is now being converted, and it is not unlikely that within the next decade or so, electrification will be authorised over the whole 1,505 miles of the trunk line from Marrakech to Tunis, of which 355 miles of the distance are already electrified. So far as Tunisia is concerned, there is little to hope for in the way of electric working except along the main line from the Algerian frontier to the capital city.

Moroccan Railways

The Moroccan Railways (Cie des C. de f. du Maroc) are in two separate and distinct systems, the western of which, extending from Marrakech to Petit Jean (see accompanying map), is now completely electrified so far as standard-gauge lines are concerned. The eastern section is formed of the newly-opened standard-gauge trunk line from Fez to Oudjda, near the Algerian frontier, which is steam worked. Between these two divisions is the Petit Jean-Fez

Passenger train hauled by double-bogie locomotive

Motor coach of the Moroccan Railways



Map showing electrified railways in Morocco, Algeria, and Tunisia

section of the Tangier-Fez Railway (Cie Franco-Espagnole du C. de f. de Tanger), which is also electrically-operated on the same principle, viz., 3,000 volts d.c.

It was the heavy phosphate traffic from the Kourigha district to the seaboard which first caused studies of electrification to be made, and the 139 km. (86·5 miles) from Kourigha to Casablanca was the first division to be converted. Electrically-hauled traffic commenced in February, 1927, and in July of the same year the service was extended to Rabat and subsequently prolonged to Port Lyautey (Kenitra). On January 15, 1934, the conversion of the line from Sidi el Aidi to Marrakech was completed, and electrification from Port Lyautey to Petit Jean is now finished. A new line from Ben Guerir to the Atlantic port of Safi is under construction, and will be electrically operated from the beginning. It is now open as far as Louis Gentil, 63 km. (39 miles), and the remaining 81 km. (50 miles) will be finished shortly. This gives a total of 643 route km. (399 miles) electrified, and 50 miles being electrified.

From the phosphate centre of Kourigha to Casablanca the line runs downhill practically the whole way, and the electric locomotives are fitted with regenerative braking to hold the trains. In 1932, the tonnage of phosphates carried down from Kourigha amounted to 975,811 tonnes, and in 1933 the amount carried by the Moroccan Railways was increased to 1,103,532 tonnes, principally by reason of the opening of the line from Louis Gentil to Ben Guerir. The trailing loads from Kourigha average 1,200 tons, but the empties are worked back in trains of 400 tons weight. The phosphate receipts amounted to 20,769,836 fr. During 1933, electrically-hauled goods trains covered a distance of 589,172 km. and electrically-hauled passenger trains 806,580 km., out of respective total train mileages of 1,174,053 km. and 1,020,798 km.; the energy consumption measured at the ingoing busbars of the substations was approximately 17,000,000 kWh.

Energy Supply and Distribution

Power is obtained from the Cie. Energie Electrique du Maroc, which owns a steam power station at Casablanca and a hydro-electric plant at Sidi Machou, on the Oum er Rebia river, due west of Sidi el Aidi. The former has a capacity of 24,000 kW. in four sets and the latter a maximum of 18,000 kW., also in four sets. The two stations are tied in, and current is generated at 5,500 volts three-phase and stepped up to 60,000 volts for long-distance transmission to Marrakech, Kourigha, and Port Lyautey, and also to Meknes and Fez, where current is supplied to the electrified section of the Tangiers-Fez Railway. At Kourigha the supply is also used for the mines of L'Office Cherifien des Phosphates, the State-controlled phosphate company.

There are ten substations on the Moroccan Railways, one at Casablanca, three between that place and Port Lyautey, four on the Marrakech line, and two on the Kourigha branch. They are all of the rotary-converter type and are situated at intervals varying from 34 to 45 miles. Sidi el Aidi substation contains three groups (for feeding the Marrakech, Kourigha and Casablanca lines) but the remainder have two only; each group comprises a synchronous motor-generator and two 500 kW. d.c. generators with a voltage of 1,500, which are connected in series. The incoming voltage is 60,000 except at Casablanca, where the substation is alongside the power plant and the generated voltage of 5,500 is taken directly to the converting apparatus.

The energy supply to the contact wire is 3,000 volts d.c., and the design of the overhead construction, converting apparatus, and rolling stock generally, was

Above : Overhead construction at Casablanca, on the Moroccan Railways

Right : Overhead construction on single line near Bône, Algerian State Railways

developed from the experience gained with the 1,500-volt lines in France. The catenary is a bronze cable of 94 sq. mm. (0·145 sq. in.) section and over many tracks there are two copper contact wires each of 107 sq. mm. (0·166 sq. in.) cross section. At a temperature of 25° C. the total resistance is about 0·1 ohm per mile. The return current is taken through the 72-lb. running rails, which are supplemented by a copper cable of 50 sq. mm. (0·077 sq. in.) section, so that the resistance of the return circuit averages 0·045 ohm per mile. The construction of the overhead line at various points may be seen from the accompanying illustrations.

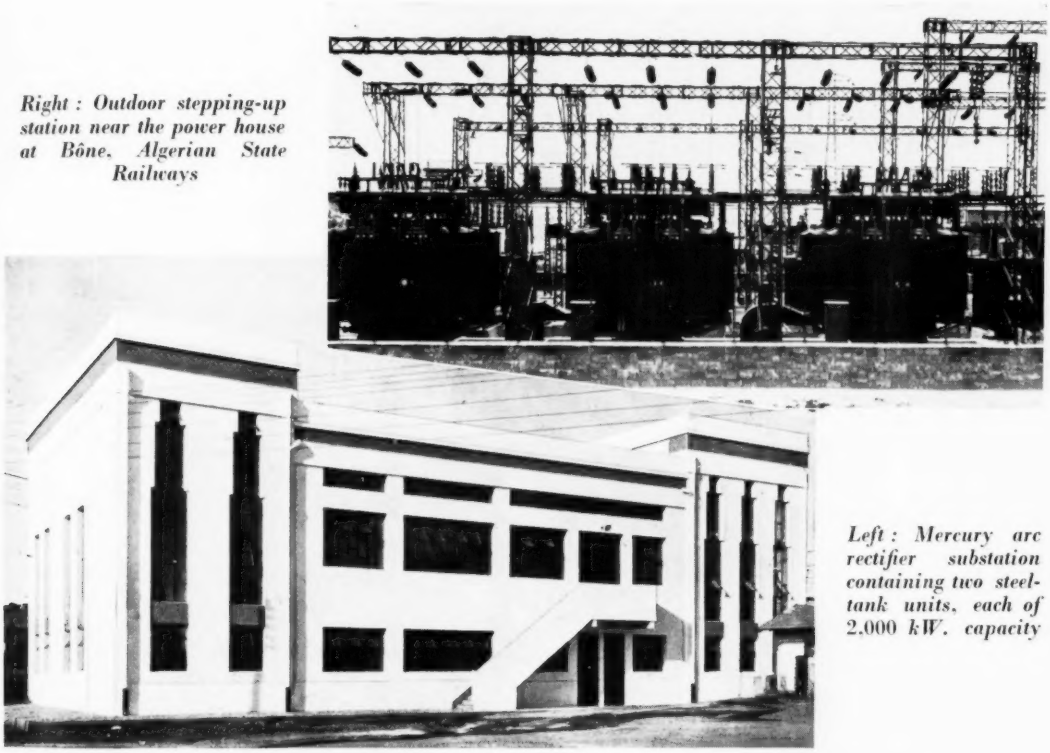
Rolling Stock

The motive power equipment consists of 26 locomotives and 10 motor coaches all fitted with multiple-unit control. The locomotives are of the Bo + Bo type with the draw and buffing gear on the bogies. The 10 locomotives set to work in 1927 weigh 73 tonnes and have a continuous output of 1,060 h.p. at 40 and 50 km.p.h. (25 and 31 m.p.h.), and a one-hour output of 1,400 h.p. at 45 km.p.h. (28 m.p.h.). The top speed was originally 60 km.p.h. (37 m.p.h.), but has been raised to 90 km.p.h. (56 m.p.h.) by a change of gear ratio. When regenerating, the four motors are all connected in series and excited from a motor-generator set; there are two braking notches giving a continuous braking force of 18,300 lb. with a regenerated current of 160 amp. 3,000 volts, and a one-hour braking force of 26,400 lb. with a regenerated current of 215 amp. 3,000 volts. The 16 subsequent locomotives have a weight of 80 metric tons, with a capacity of 1,400 h.p. continuously and 1,600 h.p. on the hourly rating. In both general and detailed design they are very similar to the locomotives of the same wheel arrangement working over the 1,500-volt lines of the P.O. and Midi in France. Electric traction with these units has enabled the time for phosphate trains between Kourigha and Casablanca to be cut by 20 per cent. to $5\frac{1}{2}$ hr. for the $86\frac{1}{2}$ miles. Passenger trains stopping at all stations take $2\frac{1}{2}$ hr. in both directions, the speed up the 1 in 80 grades between Sidi el Aidi and Kourigha being the same as that going down. Grades of 1 in 66 are encountered

Presidential train hauled by electric locomotive at Rabat-Ville station, Moroccan Railways. The tunnel is one of three running beneath Rabat, which were built under the direction of Marshal Lyautey in order to prevent the railway spoiling the old Moroccan city

between Sidi el Aidi and Marrakech, and the stopping trains take $3\frac{3}{4}$ to $4\frac{1}{4}$ hr. for the 153 miles between Casablanca and Marrakech.

The motor coaches haul three or four trailers, and are normally engaged on the Casablanca-Rabat-Port Lyautey services. Their output is 500 h.p. continuously and 700 h.p. for one hour, but they are not equipped with regenerative braking, as the maximum grade is only 1 in 125. The time taken by stopping trains is 2 hr. 20 min. to $2\frac{1}{2}$ hr. for the 128 km. (80 miles), from Casablanca to Port Lyautey. Accommodation for first and second class passengers is provided in the motor coaches, and third and fourth class seats in the trailers. The maximum speed is 90 km.p.h. (56 m.p.h.) and the tare weight 66·6 metric tons; the weight of the trailers is generally limited to 64-65 tons. Motor coaches and trailers are lined in teak and lighted electrically. A through dining-car service from Marrakech to Petit Jean is run during the day and a sleeping car service at night between Marrakech and Casablanca. Both trains have through cars for Fez and Tangier, but the night train schedules are very slow in order to prevent too early an arrival at the termini.



Right : Outdoor stepping-up station near the power house at Bône, Algerian State Railways

Left : Mercury arc rectifier substation containing two steel-tank units, each of 2,000 kW. capacity

Other Moroccan Electric Railways

Principally as the result of the heavy grades between Meknes and Fez, the Tangier-Fez Railway has recently electrified the 111 km. (69-mile) section of its main line between Petit Jean and Fez. The system of current supply is the same as that used on the Moroccan Railways, with which it connects at Petit Jean. There are three 2,000 kW. substations, located at Fez, Meknes, and Petit Jean; the two first-named are in the regenerating section and are each equipped with two synchronous motors (which permit compensation of the voltage drop by regulating the power factor) and two sets of two 500 kW. d.c. generators, the two generators in each group being connected in series. The plant at Petit Jean consists of two steel-tank 1,000 kW. mercury arc rectifiers. As the train service is not frequent, the substations come into operation automatically, starting with the approach of a train and shutting down when the load has reached the next section.

The seven electric locomotives are of the Bo + Bo type, and are generally similar to those operating on the Moroccan Railways. The weight is 80 metric tons, the continuous output 1,220 h.p., and the one-hour capacity 1,450 h.p. These locomotives can handle 600-ton passenger or goods trains single-handed up the steepest grades, and by means of regenerative braking can control a 730-ton train at a steady 31 km.p.h. (19 m.p.h.) on a down grade of 1 in 66; the air brakes are used only for stops.

The only other electrically-operated railway in Morocco is that of the Office Cherifiens des Phosphates (O.C.P.), by means of which the products of the phosphate mines are brought into Kourigha. The route mileage operated is approximately 25, and the electrification (carried out in 1931) is on the 3,000-volt d.c. system. There is only one substation, situated at Bou Djeniba, about seven miles from Kourigha at the centre of the electrified area. It is fed with three-phase current at 22,000 volts 50 cycles from the system of the Cie Energie Electrique du Maroc, and this is converted to the line current by transformers and three 750 kW. metal-clad mercury arc rectifiers, which were among the first of their kind for a tension of 3,000 volts.

Five electric locomotives maintain the service, and in design are similar to the standard Moroccan type, but the trucks are not articulated and the wheel arrangement is thus Bo-Bo. They scale 58 metric tons, and develop a continuous output of 730 h.p. at 26·3 km.p.h. (16·25 m.p.h.) with a corresponding rail tractive effort of 7,500 kg. (16,500 lb.), and an hourly output of 870 h.p.

at 24·5 km.p.h. (15·2 m.p.h.) with a tractive effort of 9,600 kg. (21,000 lb.). A maximum tractive effort of 18,000 kg. (39,800 lb.) can be exerted for one minute at starting, and this corresponds to an adhesion factor of 3·22. The top speed is 45 km.p.h. (28 m.p.h.) and the locomotive can accelerate on the level trains of 680 metric tonnes (made up of 50-ton wagons) at 0·55 ft. per sec. per sec. As the speed range is so low, only one motor grouping has been provided, viz., two groups in parallel, each with two motors in series. As with the Moroccan and Tangier-Fez Railways, the electrification of the O.C.P. line was undertaken by French companies, prominent among which was the Cie d'Entreprises Electro-Mécaniques, of Paris.

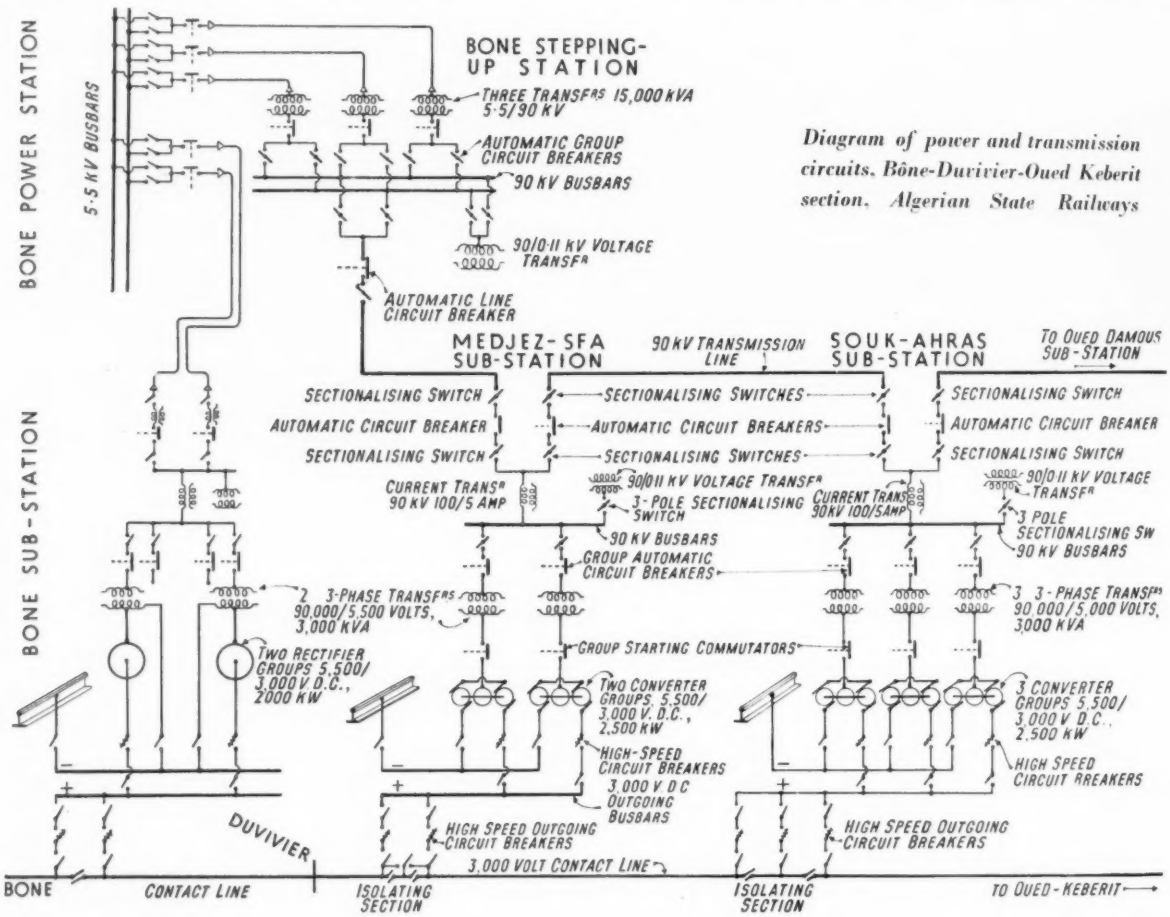


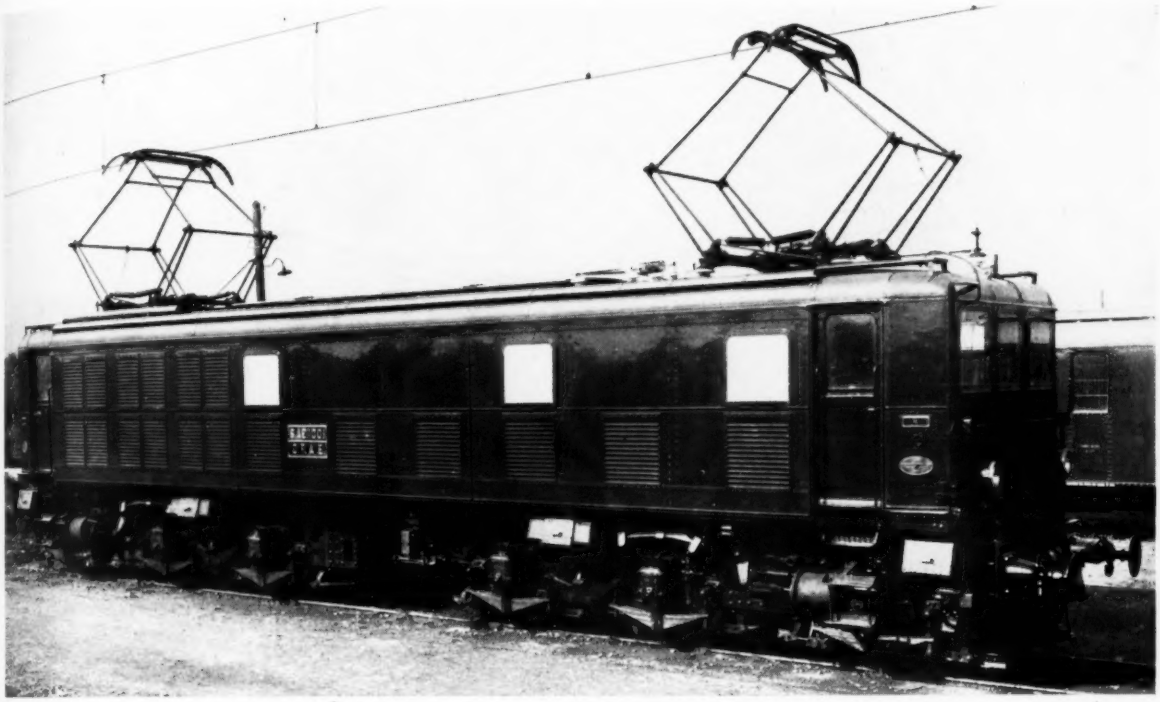
Diagram of power and transmission circuits, Bône-Duvivier-Oued Keberit section, Algerian State Railways

Algerian Railways

All the railways in Algeria are now under one management, although the ownership is still divided between the State and the P.L.M. Railway; the State-owned lines are situated principally in the eastern part of the country and the P.L.M. system in the west. One of the most densely-trafficked lines of the State network is that running from the port of Bône inland to Oued Keberit, and serving the mines of Ouenza and the phosphate district of Tebessa, the latter being reached from Oued Keberit by a narrow-gauge line.. As the yearly traffic in minerals approached 1,000,000 tons and the phosphate traffic 700,000 tons it became painfully evident that the 109 km. (68-mile) single-track division between Duvivier and Oued Keberit was not able to transport smoothly all the traffic, the principal obstacle being a sharply-curved 1 in 40 bank 11 km. (6·85 miles) long, about half of which was in tunnel, and which was against the heaviest load.

Over the whole 165-km. (103-mile) division from Bône to Oued Keberit there were in service 30 three-cylinder Decapod locomotives of the French C. de fer de l'Est type; 30 two-cylinder Decapods; and 15 two-cylinder Mountain-type steam engines. To pull 720-ton trains up the 1 in 40 bank at 15 km.p.h. (9·5 m.p.h.) it was necessary to use two Decapods, and with a traffic of 7,000 tons a day plus passenger trains and returning empties, it is not surprising that smooth operation proved difficult, and that several minor accidents occurred through the smoke nuisance in the tunnels. Careful investigations showed that electrification would cost less than doubling the track or constructing an entirely new single line for use in one direction, so it was decided to proceed with the conversion, and this work was put in hand in 1929 on the Duvivier-Oued Keberit section.

Electric operation began in 1932, and in the same year the conversion of the Duvivier-Bône line was begun, and finished in July, 1933. Although the slump of the last four years has caused a considerable reduction in the traffic, electric working has shown a considerable saving in both operating and gross expenditure, and has enabled an appreciable acceleration to be made in the timings of all trains. The 75 steam locomotives with an aggregate adhesion weight of 5,400 metric tons have been replaced by 30 electric locomotives with an aggregate adhesion weight of 3,450 metric tons. Nevertheless, the



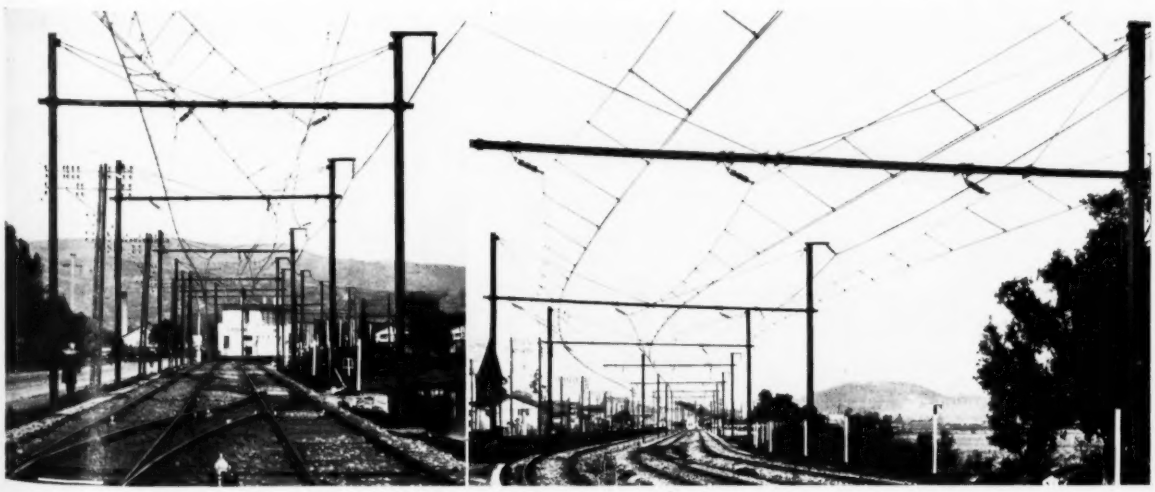
2,400 h.p. Algerian electric locomotive fitted with regenerative braking apparatus

trains from Oued Keberit to Duvivier are now increased in weight to 840 tons and hauled by one locomotive, except up the 1 in 40 grade, where double-heading is resorted to and a speed of 35 km.p.h. (22 m.p.h.) maintained.

Energy Supply and Transmission

Current is obtained from a private supply power company, the Cie. du Bourbonnais, which owns a 43,000 kW. steam plant at Bône. The electrical energy is produced by four turbo-alternator sets at a tension of 5,500 volts 50 cycles three-phase, and is stepped-up to 90,000 volts in the 45,000 kVA. outdoor plant shown in one of the illustrations accompanying this article. From the three 15,000 kVA. oil-cooled transformers the current is led through the 90 kV. busbars and automatic line circuit breakers to the substations at Medjez-Sfa, Souk-Ahras, and Oued Damous, as shown in the diagram on the opposite page. The substation at Bône adjoins the power house, and its transformers are fed direct by three-phase current at 5,500 volts.

The transmission line is comprised of steel pylons carrying the cables of the three phases from separate conductors and having the earthing wire slung between the pylon tops. It is approximately 140 km. (88 miles) long, and serves the mining district of Ouenza in addition to the railway. Owing to the exceptionally difficult nature of the country it was found impracticable to follow the



Two views near Hippone station on the Bône-Oued Keberit line of the Algerian State Railways

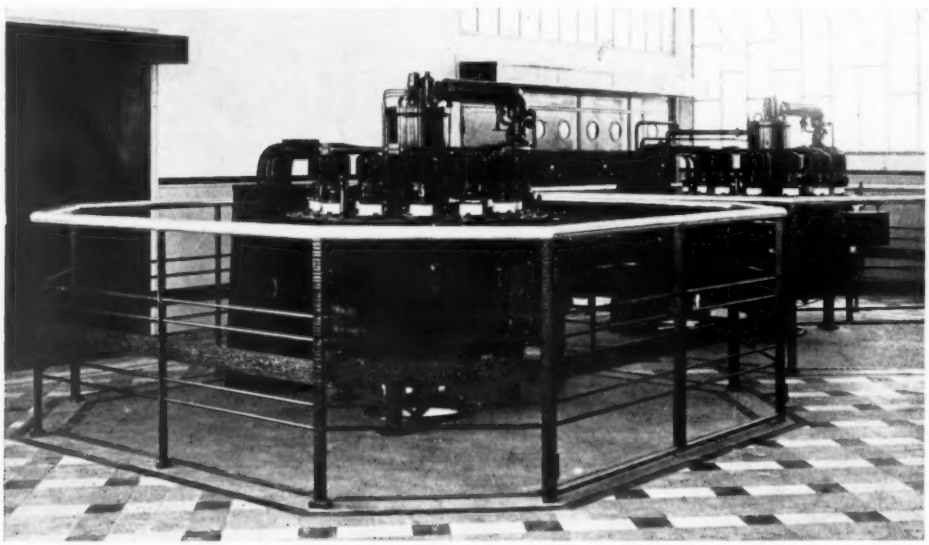
shortest route between the substations, and some pylons had to be transported in small detached pieces on the backs of men and mules. The three transmission cables are of an aluminium-steel alloy with a cross-sectional area of 238 sq. mm. (0·37 sq. in.). The earthing cable is of steel, with a cross section of 60 sq. mm. (0·093 sq. in). The pylons have an average height to the conductor arms of 20 m. (66 ft.) and are spaced at an average distance of 250 m. (820 ft.), although the maximum span is as much as 645 m. (2,100 ft.).

Substations

By using direct current with a tension of 3,000 volts in the overhead line, only four substations are required for the whole line from Bône to Oued Keberit, the spacings being 43·6, 42·2, and 65·7 km. (27, 26·2, and 41·8 miles), the greatest spacing being over the level section between Medjez-Sfa and Bône. Medjez-Sfa and Oued-Damous substations contain two 2,500 kW. rotary converter sets; Souk-Ahras, three 2,500 kW. rotary converter sets, and Bône, two 2,000 kW. steel-tank rectifiers. In the three rotary-converter substations the 90 kV. current is received through automatic circuit breakers with a rupturing capacity of 750,000 kVA., and three outdoor oil-cooled transformers. Each motor-generator set consists of a 2,800 kW. 5,500-volt Brown Boveri synchronous motor and two 1,250 kW. 1,500-volt d.c. generators fitted with separate exciters and connected in series. Each group weighs 90 tons and is mounted on one bedplate. At the normal speed of 500 r.p.m., corresponding to a periodicity of 50 cycles per sec., the commutator periphery speed is 50 m. per sec. (9,850 ft. per min.). The moment of gyration of the rotating masses of each set is 35,000 kg.m.^{2}.

Although the rating of each set is 2,500 kW. at 3,000 volts d.c., an overload of 50 per cent. can be carried for two hours and 200 per cent. for five minutes. The current produced by the d.c. machines is thus 832 amp. at rated load; 1,250 amp. at 50 per cent. overload; and 2,500 amp. at 200 per cent. overload. The current is fed to the overhead line through 3,000-volt busbars and high-speed circuit breakers capable of withstanding a short circuit of 52,500 amp. The substations are automatically-controlled on the Brown Boveri system, and can be started or stopped by the operator at the central control point, or, without his intervention, at a fixed but predetermined time. If a fault develops, the group concerned is automatically cut-out and the operator warned. The substation buildings are of concrete and carry overhead cranes for lifting the converting apparatus.

The three rotary-converter substations are all arranged to take current regenerated by locomotives running down the steep grades on the Duvivier to Oued Keberit division. The regenerated current goes back into the 90 kV. transmission system, and is paid for by the power company at 80 per cent. of the rate paid by the railway. Even with the long grades of 1 in 50 to 1 in 40, however, the total energy regenerated and sent back into the system amounts to only about 1·5 per cent. of the total consumption. As the line from Duvivier to Bône has no heavy grades, the substation at the latter place is not arranged for regeneration, and advantage of this was taken to instal mercury arc rectifiers. The two units in the substation are of the Brown Boveri type, rated at 2,000 kW. On test they gave an efficiency (rectifier alone) of over 99 per cent. at loads up to 1,000 amp., and the overall efficiency of transformer and rectifier was 96·8 per cent. from $1\frac{1}{2}$-load to full load, 96·5 per cent. at $\frac{3}{4}$-load, 95·8 per cent. at $\frac{1}{2}$-load, and 93·2 per cent. at $\frac{1}{4}$-load. The whole of the substation and overhead contact line equipment was made by the Cie d'Entreprises Electro-Mécaniques, of Paris.



Interior of substation at Bône on the Algerian State Railways. The two metal-clad mercury arc rectifiers are of 2,000 kW. capacity each, and were supplied by the Cie. d'Entreprises Électro - Mécaniques of Paris

Overhead Line

The contact line suspension is of the flexible catenary type and on the numerous curves the catenary itself is displaced towards the outside of the curve, although still attached to the arms of the masts. The suspension wires assume a slanting position influenced by gravity and the pull on curves, while the contact wire follows the line of the track very closely. By this system, which is now in extended use in various parts of the world, the masts can be kept wide apart on curves, and a considerable saving in first and maintenance costs effected without any loss of efficiency. A further point about this system of overhead construction is that it gives good results with a wide temperature range, and on the Bône-Oued Keberit line this may be 50° C. in 24 hr. On straight sections, as may be seen from the illustration on the third page of this article, both the contact wire and catenary are zig-zagged, but in opposite directions, the arms of alternate

masts being long and short to take the catenary outside or inside the contact wire.

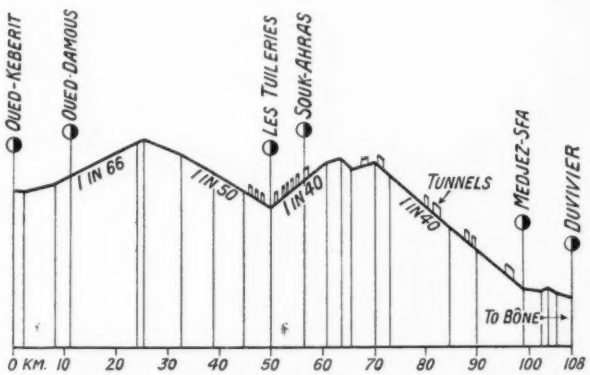
The catenary is made of steel and has a cross-sectional area of 79 sq. mm. (0·122 sq. in.). It supports a copper contact wire of 107 sq. mm. (0·166 sq. in.) area placed at a nominal height of 6 m. (19 ft. 8 in.) above rail level. Over sidings and secondary lines the section of the catenary is 53 sq. mm. (0·082 sq. in.) but the contact wire is the same as on the main line. On straight sections the average pitch of the masts is 60 m. (196 ft.), but on curves this is reduced to 50-30 m. (164-99 ft.). The feeders between the substations and contact lines are aluminium cables, with a cross-section of 400-500 sq. mm. (0·62-0·77 sq. in.), carried by porcelain insulators slung from short arms on the outsides of the masts. They are tied into the contact line every 250 m. (820 ft.), and vary in number from one to four, depending upon the power demand, four cables with a total area of 2,000 sq. mm. (3·1 sq. in.) being used, for example, on the 1 in 40 grades. In tunnels the catenary and stringers are of bronze or copper instead of steel, and the catenary has a cross section of 300 sq. mm. (0·465 sq. in.). Out on the line the masts are constructed of two 160 mm. × 60 mm. × 7 mm. (6·3 in × 2·35 in. × 0·275 in.) steel channels riveted back to back, but at stations and junctions they are fabricated of four vertical angles well cross-braced, which are used for cross-catenary supports where there are a number of tracks.

Locomotives

Goods and passenger trains are operated by 30 locomotives of the Co + Co type, but owing to the present reduced traffic all of these are not in service. When the electrification was extended from Duvivier to Bône the introduction of some Bo + Bo locomotives with a higher maximum speed was visualised, but the slump in business prevented their construction. The Co + Co locomotives were built by the Soc. d'Etudes pour l'Electrification des Chemins de fer français, an organisation comprising Schneider & Cie., Soc. Gen. de Constr. Electriques & Mécaniques Alsthom, and the Cie. Electriques de Jeumont.

Each axle is driven through twin gears with a ratio of 4·38 to 1 from a nose-suspended motor which with forced ventilation has a continuous output of 340 h.p. and an hourly capacity of 400 h.p., giving respective totals for the locomotive of 2,040 and 2,400 h.p. The armatures are wound for 1,500 volts, and three motor combinations are possible, viz., full series, with six motors in series; series-parallel, with two groups in parallel of three motors in series; parallel, with three groups in parallel of two motors in series. Actually, 30 notches are provided between starting and top speed, and eight economical speeds are possible between 9·85 and 35·25 km.p.h. (6·1 and 22 m.p.h.) by shunting various proportions of the motor fields. The maximum speed is 70 km.p.h. (43·5 m.p.h.), and the starting tractive effort 21,200 kg. (47,000 lb.), which can be maintained up to 9 km.p.h. (5·6 m.p.h.). The control apparatus is of the electro-pneumatic type.

Regenerative equipment is fitted to the locomotive, and the general auxiliary apparatus comprises a 3,000-volt 90-kW. motor generator set; a 120-volt 22-kW. generator furnishing current to the compressor motors and the traction motor fields; a variable-voltage 34 kW. generator for exciting the traction motors during regeneration; a 132 amp. hr. 65-volt cadmium-nickel battery; and three blowers for the ventilation of the main motors. Braking efforts up to 16,700 kg. (37,000 lb.) can be obtained by regeneration at speeds from 16·6 to 38·5 km.p.h. (10·3 to 24 m.p.h.) and 5,000 kg. (11,000 lb.) at 14·5 to 67·5 km.p.h. (9 to 42 m.p.h.). Two pantographs are fitted and are raised by springs and lowered by compressed air. The locomotives have an overall length of 16·4 m. (53 ft. 11 in.); a cab length of 14·6 m. (47 ft. 11 in.); a wheel diameter of 1·3 m. (51 in.); a bogie wheelbase of 4·35 m. (14 ft. 3 in.); a total wheelbase of 12·8 m. (42 ft.); and a weight in working order of 115 tonnes (113·5 tons). The bogie pivots are placed between the outer and centre axles of each bogie at a pitch of 9·1 m. (29 ft. 10 in.).



Gradient profile of Oued Keberit-Duvivier electrified line, Algerian State Railways

Operating Experiences

In the normal way the 840-tonne (828-ton) loaded trains are made up of double-bogie mineral wagons, with a gross individual weight of 59 tonnes and four-wheeled phosphate wagons of 30·7 tonnes; on the return journey the empties are marshalled into trains of 300 tonnes weight and are worked all the way by one locomotive, whereas the loaded trains are piloted between Les Tuileries and the summit. How heavily the traffic has slumped during the past few years is shown by the accompanying table.

Year	Tonnes of phosphates	Tonnes of minerals	Total Tonnage
1928	681,895	755,060	1,436,955
1929	711,370	887,810	1,599,180
1930	702,440	1,280,200	1,982,640
1931	460,870	299,920	760,790
1932	518,580	224,840	743,420
1933	565,300	375,580	940,880

The most remarkable feature of this table is the drop of over 75 per cent. in the mineral traffic between 1930 and 1931. The following figures and observations refer only to the Oued Keberit-Duvivier section, as the Duvivier-Bône line was not brought into full operation until July, 1933, although for two months previously electrically-hauled trains were worked to Bône with current fed into the line from Medjez-Sfa substation as the plant at Bône was not ready. Of course, this led to a serious drop in voltage and speed near Bône. During 1933, the total distance covered by the 29 locomotives in service was 900,000 km. (56,000 miles), or 33,900 km. (21,000 miles) per unit, this figure including shunting duties, and allowance for the fact that only 21 locomotives were in the list at the beginning of the year. The 30th locomotive was not put into traffic until March, 1934. The train-km. amounted to 773,643 (481,000 train-miles), the trailing tonne-km. to 353,438,172 (215,000,000 ton-miles), and the gross tonne-km. 459,872,052 (281,000,000 ton-miles).

In 1933 the total energy consumed was 16,504,770 kWh., of which 16,122,018 kWh. was for traction purposes, and the remainder for works and shed power and station lighting. The regenerated energy going back into the system amounted to 224,775 kWh., giving a net

traction consumption of 15,897,243 kWh. The consumption per trailing tonne-km. measured at the ingoing busbars of the substations was therefore 45·1 watt-hr. (74 watt-hr. per trailing ton-mile), and 34·5 watt-hr. per gross tonne-km. (56·5 watt-hr. per gross ton-mile). Although the maximum peak demand for energy over the whole line was about 8,000 kW., the maximum instantaneous regeneration was only 400 kW., and was thus easily absorbed into the electrified system of the Cie. du Bourbonnais. The regenerated energy as actually measured on the locomotives was about 15 per cent. of the total consumption, but most of this was absorbed by direct return to the overhead line and some in the substation plant, so that actually only 1·5 per cent. went back into the system.

Over the Oued Keberit to Duvivier line it is estimated that the saving in operating charges amounted to 13,400,000 fr., and to 2,240,000 fr. after all capital charges had been met. Even better results could be shown if traffic was to rise to the 1928-30 figures, but in any case a further saving should result from the electrification of the Duvivier-Bône line, and the train times have been cut by 40 per cent. on the mountain section and by 25 per cent. on the level division. The benefits of electrification have been so obvious that a sum of 200,000,000 fr. has been ear-marked for conversion work during 1934-35 on the Duvivier-Guelma and Souk Ahras-Ghardimaou sections of the main Algiers-Tunis line, with a combined length of 75 km. (46·5 miles).

Letter to the Editor

(*The Editor is not responsible for the opinions of correspondents*)

Electric Locomotive Wheel Arrangements

28, Victoria Street,
London, S.W.1.
November 5, 1934

To The Editor, The Railway Gazette

Dear Sir,—In your *Electric Railway Traction Supplement* of October 19, you refer to the subject of nomenclature for electric locomotive wheel arrangements, and you express disappointment with the recommendations recently made by this Institution as published in B.S.S. 560-1934.

You have referred to this matter, I find, on two occasions, namely, October 27, 1933, and June 1, 1934, and from the articles in these issues it appears that the system of nomenclature you have "consistently urged" is precisely that which has been standardised in B.S.S. 560.

In your notes of October 19, there appears to be a suggestion that the subject has been dealt with in a half-hearted manner. In justice to the members of our committee, therefore, I feel bound to point out that, not only was the committee a very representative and responsible one, but it gave the matter the most thorough consideration, and spent many meetings reviewing the available literature on the subject and the known practice in Europe, America, and other parts of the world. Furthermore, the committee sought the views of a large number of responsible engineers both at home and abroad, before issuing their recommendations.

As regards the suggestion that "the standards are not even right as far as they go," it must not be overlooked that the formulæ to which you draw particular attention are given merely as *examples of combinations* of the standard symbols. Thus the formulæ 1C+C1 and 2-B+B-1 are given as types of symbols and not as types of locomotives.

Our committee was in full agreement with your view that the nomenclature should be simple and should not include too much information. The symbols given in B.S.S. 560 were based on this very principle, but are not intended to denote all the several characteristics of a loco but only to indicate the general type. The people who have occasion to use these symbols have some trained idea of the subject, and do not expect a lot of particulars in a formula. They usually know the particular loco or at least know sufficient of the particular loco to fill in the necessary details. It may be conceded that in some respects the system of classification is incomplete in so far as articulation, multiple operation, pony axle trucking and other arrangements are concerned, but after consideration of a vast amount of literature on the subject, it was generally agreed by all who were consulted that such particulars were best left to the accompanying script or to the general specification of the locomotive.—Yours very truly,

P. Good,
Deputy Director, British Standards Institution

[In spite of Mr. Good's explanation, we do not think that the B.S.I. has done anything to evolve a principle of wheel notation which can be applied to any type. Moreover, we still consider that (for example) the formula 1C+C1 quoted does not correspond with the description given, and although the people who have occasion to use these symbols may have some trained idea of the subject, the man who knows sufficient of the particular locomotive is the one least interested. The purpose of the symbol is to tell the other party, who knows little about the particular job, just what he wants to know in the minimum of space, and the 1C+C1 example is an instance of how he may be misled by the specification of the B.S.I.—Ed. *R.G.*]

Italian Railway Activities.—The Italian State Railways are about to put into service a load distributing central office for the purpose of utilising in the best and most economical manner the production of electric current in the various generating stations. The values of active (kW.) and of reactive power (kVAR) will be measured continuously at the various plants and transmitted by telephone wires to the central office, where they will be registered on special apparatus, of which there is one for each plant. A special integrator will add the total of kW. On the basis of this information the central office will make suitable arrangements for the distribution of kW. and kVAR by transmitting the necessary orders to the plants.

The first lines whose electrification under last year's scheme have been completed within the current year are the following:—

	Miles			
Naples–Salerno	33½	d.c.	3,000	volts.
Torre Annunziata–Gragnano	8	,,	,,	
Bolzano–Trento	34¾	3-ph.	3,600 volts	16⅔ cycles
Bolzano–Merano	19⅞	,,	,,	,,
Trofarello–Cuneo ..	46½	,,	,,	,,
Fossano–Ceva	24¼	,,	,,	,,
	167			

All these lines were opened to regular electric traction in October, and a further 1,074 route miles of the Italian State Railways is at present being converted from steam operation.